Supracricoid Partial Laryngectomy:
Swallowing, Voice, and Speech Outcomes

Kimberly T. Webster, MA, MS; Robin A. Samlan, MS, MBA;
Bronwyn Jones, MB, BS, FRACP, FRCR; Kate Bunton, PhD; Ralph P. Tufano, MD

Objectives: The purpose of the study was to describe the swallowing and vocal function of patients after supracricoid partial laryngectomy (SCPL) as they changed over the first postoperative year.

Methods: Ten patients with laryngeal carcinoma underwent SCPL at Johns Hopkins Hospital between August 2003 and May 2005. Clinical and videofluoroscopic swallowing examinations and perceptual, acoustic, aerodynamic, and videostroboscopic voice evaluations were completed before operation and at 3 weeks (swallowing only) and 2 (voice only), 6, and 12 months after operation.

Results: The mean time to gastrostomy tube removal was 82 days. The patients tolerated an increased variety of foods over the first postoperative year. All patients initially used therapeutic strategies to swallow safely, and some still required them at 1 postoperative year. Over the year, the perceptual ratings of voice quality improved significantly. There were no consistent changes in acoustic or aerodynamic measures. The number of patients who used multiple vibratory sources to phonate increased over the year.

Conclusions: The patients tolerated regular diets, yet continued to exhibit silent aspiration and a variety of decompensations. Their voices were breathy, rough, and strained. Their voice quality ratings improved over the year. Group changes were not captured, and it appears that the changes in speech and voice 2 months after surgery were subtle.

Key Words: functional outcome, supracricoid laryngectomy, swallowing, voice.

INTRODUCTION

Supracricoid partial laryngectomy (SCPL) is a partial laryngectomy procedure used for select patients with T1b, T2, T3, and T4 supraglottic and glottic carcinoma.1-2 The surgical resection includes the vocal folds, ventricular folds, paraglottic spaces, and thyroid cartilage. The epiglottis, preepiglottic space, and arytenoid cartilage may also be resected. The advantages compared to total laryngectomy are the absence of a permanent tracheostoma and retention of physiologic voice and swallowing. Because SCPL results in resection of the most inferior (vocal folds) and sometimes the most superior (epiglottis) levels of airway protection, chronic aspiration is a potential problem.

Patients attempt to swallow safely with neoglottic closure of the criocartilaginous unit and tongue base for cricohyoideopexy (CHP) or of the criocartilaginous unit, tongue base, and epiglottis for cricohyoideopexy (CHEP). They reportedly return to full diets over the first postoperative year.2-4 Videofluoroscopic and flexible fiberoptic endoscopic swallowing studies have identified oral and pharyngeal decompensations.5-9

The voice quality following SCPL is breathy, hoarse, rough, and strained, and Voice Handicap Index scores identify a degree of patient-perceived voice-related handicap.8,10,11 Acoustic and aerodynamic measures are abnormal or unable to be validly measured.8,11 Speech is intelligible, except in noisy environments,6,12 but is characterized by an abnormal speaking rate and phrasing.13

We undertook a pilot study to describe changes in the swallowing and vocal function of patients with SCPL over the first postoperative year. Improvements in swallowing safety and efficiency; return to normal diet, speech, and voice quality; and decreased patient perception of handicap were expect-
ed. This research was conducted with the approval of our Institutional Review Board.

**MATERIALS AND METHODS**

**PATIENT DEMOGRAPHICS**

Fourteen consecutive patients with carcinoma of the larynx who appeared to meet criteria for SCPL consented to participate in this study between August 2003 and May 2005. Four of these patients underwent total laryngectomy — 3 because of more-extensive tumors — and 1 declined SCPL after preoperative counseling. The surgical procedure was described in a previous publication.\(^{14}\) Nine men and 1 woman (mean age, 56 years; range, 39 to 77 years) constituted the study group. The SCPL was a salvage procedure for 4 participants, who had preoperative radiotherapy. The other 6 patients underwent the SCPL as a primary therapy. The margins were negative on resection of the primary tumor; therefore, no participants required postoperative irradiation. Five patients required resection of 1 arytenoid cartilage, and 2 required CHP. Participant characteristics are described in Table 1.

**PROCEDURES**

All participants underwent preoperative counseling. Swallowing, speech, and voice were evaluated before the operation and at 3 postoperative visits: 3 weeks (swallowing only), 2 months (voice only), 6 months, and 12 months.

At the time of SCPL, tracheostomy and gastrostomy tubes were placed. The patients were asked to expectorate secretions while awake for the first 15 postoperative days. Swallowing therapy began on day 15 with saliva swallows using an “airway protected swallow” maneuver based on a technique described by Ruiz and Crevier-Buchman.\(^{15}\) The maneuver has 5 steps: slight chin tuck, maximal tongue retraction, breath hold before and during the swallow, effortful swallow, and coughing if necessary. Pureed foods were typically introduced on day 15, with weekly addition of consistencies in the following order: solids, thick liquids, and thin liquids. The swallowing treatment was modified on the basis of findings from videofluoroscopic swallow studies. Swallowing studies were conducted by a speech-language pathologist (K.T.W.) and a radiologist (B.J.), with the patient standing upright in lateral and frontal projections. Consistencies were presented in the following order: 5 mL thin liquid, 10 mL thin liquid, 5 mL thick liquid, 10 mL thick liquid, 2 teaspoons puree, 1 bite of graham cracker, and 3 consecutive cup sips of thin liquid. Protocol variations were required for patient safety. The airway protected swallow was used for all trials unless the speech pathologist, radiologist, and patient felt that it was safe to try to swallow with no strategy. The speech pathologist and radiologist rated the following as normal, mildly impaired, or moderately to severely impaired: bolus control and manipulation, soft palate elevation and closure, nasopharyngeal retraction, pharyngeal constriction, epiglottic tilt, laryngeal elevation, arytenoid mobility, retention of the bolus from base of tongue to pyriform sinuses, cricopharyngeal opening, and esophageal function. Penetration and aspiration of 4 consistencies with and without the strategy were documented. The time to gastrostomy tube removal was recorded. The SWAL-QOL,\(^{16}\) a dysphagia-specific quality-of-life

<table>
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questionnaire, was administered at 6 and 12 months after surgery. To assess intrarater error, the speech pathologist and radiologist re-rated 5 randomly selected swallow studies. There was exact agreement for 77% of the 70 items rated.

The patients were offered voice therapy to decrease vocal fatigue, improve voice quality, and increase loudness and intonation. The therapy included breath hold and release, varying the amount of “throat squeeze,” breath modification, equalizing quality and loudness while sustaining vowels, maintaining the voice quality with gradual increase and decrease in loudness, 3-note scales, and tongue release exercises.

The Voice Handicap Index, acoustic recordings, aerodynamic testing, and videostrobscopy were completed before surgery and at 2, 6, and 12 months after surgery. Voice samples were recorded with an AKG 420 head-mounted microphone placed 2 to 3 inches from the right corner of the mouth and were digitized at 4,400 Hz into Computerized Speech Lab 4400 (KayPENTAX, Lincoln Park, New Jersey). The speech sample included 3 repetitions of a sustained /a/, 5 sentences from the Consensus Auditory Perceptual Evaluation of Voice, and picture description. Three speech-language pathologists who were not otherwise involved in the study rated 4 voice parameters (overall voice quality, roughness, breathiness, and strain) and 4 speech parameters (overall intelligibility, naturalness, articulatory precision, and intonation) from randomized audio recordings of 5 standard sentences and approximately 30 seconds of connected speech. They used 100-mm visual analog scales with labeled anchors (eg, normal and severe). Wideband spectrograms and long-term average spectra of sustained /a/ were examined for formant structure and fundamental frequency by means of Praat. Oronasal airflow and intraoral air pressure were obtained with an aerodynamic system from Biocommunication Electronics (Madison, Wisconsin). The data were digitized into the “aero” program of TF32 (Madison, Wisconsin). The measures included mean airflow during sustained /a/, peak intraoral air pressure during /p/ from repeated syllables /pipip/, and phonation threshold pressure. Two additional speech-language pathologists not otherwise involved in the study used categorical scales to rate the vibration of each structure and neoglottic closure from randomized videostrobscopic examinations. Their ratings were averaged.

Descriptive group statistics are presented for each measure. Although the sample size is limited and alpha inflation is a concern, a variety of inferential tests comparing scores at each visit were used (alpha of 0.05) to identify the most promising variables for future, larger studies.

RESULTS

Data were available for every study visit for 7 patients. Subject 2 was lost to follow-up after the second postoperative visit, and subjects 8 and 13 missed the 6-month follow-up.

SWALLOWING

Gastrostomy Tube Removal. The feeding tubes were removed between days 29 and 169 (mean, 82 days; SD, 47 days). None of the subjects were found to have aspiration pneumonia during the study period. Of the 4 subjects who retained their feeding tubes the longest, 2 had reconstruction with CHP and 3 had an arytenoid cartilage resected. Age did not appear to be a factor.

Videofluoroscopic Swallowing Studies. The Figure shows the number of patients who demonstrated no more than minimal aspiration with and without strategies. The patients safely swallowed purees and solids before thin liquids. At 3 weeks, no patients tolerated thin liquids, even when using the airway
protected swallow. Three patients had significant aspiration of purées, none of whom had arytenoid resection and 1 of whom had CHP reconstruction. One of the 3 had preoperative radiotherapy. By 6 months, swallowing was generally safe, with strategies needed only for thin liquids. One year after surgery, approximately 80% of the patients safely swallowed all consistencies, yet 67% (6 of 9) of the patients silently aspirated at some point during the examination. The 2 who aspirated significantly at 1 year had an arytenoid cartilage resected, and 1 had undergone CHP. The 3 subjects who did not silently aspirate had undergone CHEP. One patient had an arytenoid cartilage resected, and 2 had undergone preoperative radiotherapy.

Common videofluoroscopic swallowing study findings were impaired base-of-tongue retraction, pharyngeal constriction, epiglottic tilt, hyo-"laryngeal" elevation, and cricopharyngeal function. Retention in the valleculae and/or pyriform sinuses, laryngeal penetration, and aspiration occurred. Neoglottic closure at the level of the arytenoid cartilages was difficult to assess during the swallow by videofluoroscopy, but videostroboscopic evaluations showed small gaps during coughing and phonation. None of the oropharyngeal decompressions were associated with aspiration, according to Kruskal-Wallis rank sum tests (p > 0.05).

To determine change over time, we completed Wilcoxon signed rank tests for several swallow study parameters between the first (3 weeks) and final (12 months) postoperative assessments. No statistically significant differences were found (p > 0.05). Of note, base-of-tongue retraction improved with therapy for 3 of 9 patients.

**SWAL-QOL Findings.** Seven patients completed the SWAL-QOL at 6 months, and 9 at 12 months. Sixty-seven percent of patients (4 of 6) reported eating regular diets by 6 months, and 89% (8 of 9) by 1 year after surgery. The remaining subject ate soft foods. She had undergone CHEP with both arytenoid cartilages intact, and no preoperative radiotherapy.

At 6 months, 57% of patients (4 of 6) reported sometimes choking on food. At 12 months, 44% (4 of 9) continued to sometimes choke on food. The 4 included the 2 subjects who underwent CHP. Of the 2 who had undergone CHEP, 1 had an arytenoid cartilage resected and 1 had undergone preoperative radiotherapy. All 7 subjects reported drinking thin liquids by 6 months, although 86% (6 of 7) choked at least sometimes. At 1 year, 67% (6 of 9) continued to choke some of the time. Two of these 6 subjects reported choking often. Both had undergone CHP reconstruction. The 3 subjects with minimal choking on liquids had undergone CHEP. One had an arytenoid cartilage resected, and 2 had undergone preoperative radiotherapy.

**Therapy.** Therapy was individualized according to videofluoroscopic findings and response to maneuvers during the examination. For example, 1 patient demonstrated asymmetry of pharyngeal constrictor strength and benefited from use of a head turn. Patients with CHP did not benefit from use of a chin tuck and had an increased risk of aspiration with this posture. Several patients required more directed exercises for tongue base retraction.

**SPEECH AND VOICE**

*Patient Perception of Handicap.* The mean total Voice Handicap Index score decreased from 61.28 (SD, 16.77) to 55.00 (SD, 15.44) from 2 to 12 months after surgery; however, this decrease was not statistically significant on a related samples *t*-test (p > 0.05). Both 2-month and 12-month values were consistent with those of patients who report a severe handicap. The 2 subjects who rated the least amount of voice handicap at the final postoperative visit had an arytenoid cartilage resected and had undergone preoperative radiotherapy. The 2 subjects who rated the most voice handicap had undergone CHP reconstruction. The patients also rated the severity of their voice disorder. At 1 year after surgery, 1 of 7 rated the voice as severely, 4 as moderately, 1 as mild to moderately, and 1 as mildly impaired. In comparison to the 2-month visit, 4 of the subjects rated their voices as less severely impaired, 4 patients’ ratings did not change, and none rated their voices as more impaired. Their employment status did not change for 9 of 10 patients. One patient left his job because he could not communicate with coworkers over noise.

**Perceptual.** The voice quality was moderately to severely impaired, characterized by roughness, breathiness, and strain. Table 2 shows the average percep-
tual ratings of voice quality across study points. Related samples t-tests identified differences in overall severity ($t(8) = 2.556; p = 0.034$) and breathiness ($t(8) = 4.093; p = 0.003$) between 2 and 12 months after surgery. The 2 patients whose voices were rated as most impaired had both arytenoid cartilages preserved, and neither had undergone preoperative radiotherapy. One had undergone CHP reconstruction, and 1 had undergone CHEP. The patient rated as the breathiest had both arytenoid cartilages, did not have preoperative irradiation, and had undergone CHEP reconstruction.

Speech was rated as moderately unnatural (toward "bizarre" on the naturalness continuum) and monotone. Articulatory precision and intelligibility were mildly impaired. Table 2 shows the average perceptual ratings of speech production across study points. A related sample t-test determined that speech became less monotone ($t(8) = 4.606; p = 0.002$) from 2 to 12 months after surgery. None of the other changes were statistically significant ($p > 0.05$).

**Acoustic Analysis.** The voice signal at both presurgery and postsurgery visits was aperiodic in all cases, and commercially available algorithms for detecting fundamental frequency could not be used. The aperiodicity prevented calculating frequency range and frequency-based perturbation measures.20

Visual inspection and comparison of long-term average spectra showed an upward shift in formant frequencies (F1, F2, F3, F4) for the 3 postoperative samples compared to the presurgery sample in all 9 patients. Audio samples were not calibrated, so spectra were normalized by setting the amplitude of the estimated F1 to 0 dB. Two patients demonstrated a less distinct formant structure (ie, widened formant peak and shallower valleys) at 2 months than at later follow-up visits. Five patients showed no changes over time, and 1 patient had an upward shift of the formant frequencies at 2 and 6 months, but they returned to near-preoperative values by 1 year. The observed shift in formant frequency moved some of the vowels out of the typical vowel space for /æ/.

**Aerodynamic Analysis.** The mean oronasal airflow was 383.4 mL/s (SD, 325.4) at 2 months and 356.3 mL/s (SD, 217.8) at 1 year after surgery. The peak intraoral air pressure during /p/ was 14.8 cm H2O (SD, 6.2) at 2 months and 18.01 cm H2O (SD, 8.0) at 1 year. The phonation threshold pressure was 8.06 cm H2O (SD, 3.6) at 2 months and 4.66 cm H2O (SD, 1.6) at 1 year. None of these differences were statistically significant ($p > 0.05$).

**Videoendoscopy.** The vibratory sources included the arytenoid cartilages, aryepiglottic folds, and epiglottis, depending on the extent of the excision. At 2 months, 63% of patients (5 of 8) used all available sources. Seventy-one percent (5 of 7) used all sources at 6 months, and 78% (7 of 9) at 12 months. The degree of vibration, however, did not significantly increase between 2 and 12 months, according to the Wilcoxon signed rank test ($p > 0.05$).

**DISCUSSION**

This study is unique, because swallowing and voice were evaluated at several time points over the first postoperative year. This small-sample pilot study yielded a number of interesting findings and directions for future research.

Many decompensations were found in addition to the expected difficulty with airway protection during the swallow. Consistent improvements in swallowing parameters did not occur over time, with the exception of improved tongue base retraction. Some of the deficits have been reported by previous researchers,5,9,21 including reduced base-of-tongue retraction, limited epiglottic tilt, decreased hyo-"laryngeal" elevation, reduced cricopharyngeal opening, and retention in the valleculae and/or pyriform sinuses. Additionally, premature spillage and reduced pharyngeal contraction occurred. These findings may be surprising, as they do not directly relate to resected or reconstructed anatomy. Consistent with other studies, penetration and aspiration occurred.9,21 Silent aspiration was prevalent in our study and persisted for some patients at 12 months. The sensory feedback from the areas removed is invariably disturbed despite the surgical preservation of the neurovascular pedicle. Some patients might not regain full sensation of all of the remaining mucosa, especially at the margins of resection, for reasons not fully clear. Studies of glottic and subglottic sensation in a reconstructed larynx are warranted.

Neither significant aspiration early in recovery nor the final swallowing outcome appeared to be related to the structures removed or to preoperative radiotherapy. The 2 subjects who had undergone CHP, however, were among those who reported continuing to choke on foods and liquids 1 year after surgery. The subject with the lowest score on the cognitive screening was also among those who reported choking.

The airway protected swallow is a useful strategy for many SCPL patients and certainly addresses a majority of potential swallowing deficits. The chin tuck component should reduce the risk of aspiration before the swallow. The retracted tongue, breath hold, and cough sequence should improve neoglott-
tic airway protection during the swallow. Individualized therapy based on instrumental assessment is recommended. Videofluoroscopic swallowing studies should not be avoided because of fear of aspiration; rather, they are necessary to determine and address the nature of any potential aspiration. Given that a majority of patients are at risk for aspiration of thin liquids early in the recovery after SCPL, it is reasonable to begin therapy with a general protocol of avoiding thin liquids until an airway protection strategy is mastered and adequate healing occurs. In this study, patients were successful when they first practiced airway protection maneuvers during saliva swallows and then progressed to purées and solids. Many patients stopped using strategies between their 3-week and 6-month follow-up visits. It is clearly, however, not safe for all patients to stop consciously focusing on the strategy for all consistencies, even 1 year after surgery. Their swallowing should be reevaluated as patients age or their medical status changes and patients are no longer able to tolerate some aspiration.

Voice quality was perceptually rated as less impaired and less breathy over the study period; however, roughness increased. It is possible that patients had to increase roughness in order to decrease breathiness. The total Voice Handicap Index score of 55 (SD, 15.44) at 12 postoperative months was within the range of previously reported scores for this population: 29.911 and 61.8 The change in scores from 2 to 12 months was not statistically different for the group, yet 50% of the patients rated their voices as less impaired by the final visit. Perhaps they acclimated to the level of handicap over time. The 2 patients who had undergone CHP rated their handicap as more severe than did the other patients, and expert listeners rated the voice quality of 1 of the patients who had undergone CHP as severely impaired. A larger study comparing voice quality after CHP versus that after CHEP would be necessary to conclude that the voice is worse after CHP.

The videostroscopic data were similar to those of other studies with respect to which structures vibrated.12,22 Over time, the number of structures involved in vibration increased, so that by 1 year, 78% of subjects used all sources available to them (arytenoid cartilages, aryepiglottic folds, and epiglottis if present). The degree of vibration for individual structures did not increase.

The spectra were consistent with the perceptual data and with other studies11 in identifying rough and noisy waveforms. The aerodynamic findings of high airflow, intraoral air pressure, and phonation threshold pressure were consistent with findings by Dworkin et al.8 No acoustic changes were noted during the first postoperative year.

Decreased intelligibility and articulatory precision are consistent with the subtle changes in postoperative formant values for /al/. Some subjects generalized the swallowing strategy of tongue retraction to speech production, and needed instruction to release the tongue while talking.

CONCLUSIONS

Swallowing improved steadily over the first postoperative year. Although most patients tolerated a normal diet without strategies by 12 months, some patients continued to require them. One year after surgery, most patients continued to exhibit some oropharyngeal decompensations and, sometimes, silent aspiration. The voice quality ratings were less severe at 12 months than at 2 months after surgery, and some patients demonstrated measurable improvements over that time. Group changes were not captured with the measures used in this study, and it appears that the changes in speech and voice after 2 months were subtle.

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REFERENCES


